IMPROVING RELIABILITY & WRITING SPECIFICATIONS

(08)

IMPROVE

- To advance to a better state or quality; make better,
- To increase the productivity or value of,
- To make beneficial additions or changes.

BESIDES MEASURING RELIABILITY REMEMBER:

- **We never just want to measure things (our finances, parts tolerances and deviations, safety, reliability)!**
- **But we always need to ask: How can what we are measuring be improved?**
- **How can we educate others to improve it?**
- **What changes need to be made to improve it?**

OBJECTIVES:

- What programs can be instituted to improve reliability?
- How do these programs have to be performed?
- How can design changes improve reliability?
- What is fault tolerance, fault avoidance and robust design?
- How can the manufacturing process be improved?
- How is the product performing in the field?

OUTLINE

- **Fault Avoidance/Fault Tolerance**
- **Robust Design**
- **Sensing Failures**
- **Failure Analysis**
- **Worst Case Failures**
- **Allocation of Failure Rates**
- **Parts Derating**
- **Non-operating Failures**
- **Standardization**
- **Manufacturing Process Improvement**

DEFINITIONS:

- **FAILURE ANALYSIS: The analysis of each failure to determine the root cause and the implementation and verification of corrective action so the failure does not reoccur. This results in product improvement.**
- **FAULT AVOIDANCE: This is an approach or methodology to increase reliability by reducing the possibility of a failure by increasing the reliability of individual components.**
- **FAULT TOLERANCE: The designed in characteristics that maintains prescribed functions or services to users despite the existence of fault(s).**
- **ROBUST DESIGN: A design that gives allowance for errors, faults and damage so that despite their occurrence the system continues to function.**

CAN YOU AVOID FAILURE?

Reduce Parts Count ← ~~FAILURE~~

Test for ← **FAILURE**

Robust Design ← FAILURE

Split Systems ← FAILURE

FAULT AVOIDANCE
Methodology:

- careful signal path routing
- screening incipient failures
- simplification.
- worst case design
- testing components
- using high reliability components
- specifying reliability for all components and subsystems.
- determine cause and corrective action when failures occur in tested prototypes.

ROBUST DESIGN

- Modular design
- Materials which "inhibit" crack growth.
- Special coatings to inhibit corrosion, etc.
- Special lubricants
- Interlocking systems
- Uniform loading/deformation
- Avoiding stress concentrations
- Designing for shipping and storage
- Worst/worst design--designing for worst tolerance or failure of another member.

SENSING IMPENDING FAILURES

- Vibration monitors for rotating equipment (sense change in vib. signature).
- Bearing monitors (sense ultra-high pitch bearing noise).
- Crack growth monitors (strain gauges sense crack propagation).
- Acoustic crack growth monitors (listening for crack growth).
- Monitoring cumulative damage.
- Analyze anomalies in circuit outputs.
- Sense computer output anomalies.
- Self-checking / self-monitoring / built-in-test.

WORST CASE FAILURES

- What is the worst thing (failure mode) that can happen?
- Can you live with it?
- Can you test to be sure it won't happen?
- Can you design out the failure mode?
- Can you detect the approach of the failure mode with special inspections?
- Can you perform special maintenance to eliminate the failure mode?
- Can you specify operational constraints to avoid the failure mode?

Allocation of Failure Rates and Reliability

Background:

- **Reliability requirements for most government contracts only provide a system level value. The prime contractor will then apportion this value to the subsystem level and flow those requirements down to the subcontractors. To work out the required subsystem and component level reliability requirements an allocation process should be utilized.**

Example

- **Launch vehicle with an estimated parts count of 10,000 and a system level reliability value of 0.99 and a mission time of 0.5 hour.**
- **It is assumed that all components must function for mission success and that all components function for entire mission length.**

$$R_{missile} = exp(-\lambda_m t_m) = 0.99 = e^{-0.01} = exp^{-\lambda(0.5)}$$

$$\lambda_m(0.5) = 0.01 = (0.01/0.5) = 0.02\ failures/hr$$

Example (continued)

$$\lambda_c = \lambda_m / \textit{number of parts} = 0.02/10000 = 2 \text{ x } 10^{-6}$$

(components)

$$R_c = exp\text{-}(\lambda_c t_c)$$

$$= exp\text{-}(2\text{x}10^{-6}(0.5)) = exp\text{-}(1\text{x}10^{-6})$$

or 2 failures / 10^6 hours

when $\lambda t <= 0.01$

$R_c \cong 1 - \lambda t$ *so* $R_c = 1 - 0.000001$

$R_c = 0.999999$ *or in short hand form*

$$R_c = 0.9_5$$

Alternate method

$$R_c = (R_s)^{1/n}$$

Where:

n **= the number of components.**

R_s **= System reliability**

R_c **= Component (part) reliability**

For our launch vehicle example we have:

$$R_c = (0.99)^{(1/10)^{\wedge}4} = (0.99)^{.0001} = 0.95$$

IMPROVING SYSTEM RELIABILITY THROUGH PARTS DERATING--Example

Two 20-V MIL-C-3965 type CL-24 capacitors operate at 60°C. One is at 18 V and the other is at 10 V.

Stress ratio = (Operating Voltage)/(Rated Voltage)

Therefore, one capacitor has a stress ratio of:

Stress ratio = **(18V)/(20V) = .9**

and the other has a stress ratio of:

Stress ratio = **(10V)/(20V) = 0.5**

Example Continued:

From MIL-HDBK-217 Sec. 10.13, Table for MIL-C-3965 type C20 capacitors we have:

Moving horizontally across 60 °C line to 0.5 and 0.9 vertical columns the failure rates can be read directly.

$\lambda_{0.5}$ = 0.019 failures per 10^6 hours

$\lambda_{0.9}$ = 0.079 failures per 10^6 hours

Use this information only for comparative purposes. Predicted life also needs to take into account temperature, environment, etc.

Protect Against Non-Operating Failures

- **Consider the operating life test from RP-1253, p. 35.**
- **Parts continue to fail even when not in use. In general parts fail less frequently when not operating because failures are accelerated by operating stresss. But all components tend to degrade even when not in use:**
- $R_s = R_{operating} R_{non\ operating}$
- **The expression for system reliability becomes: the nonoperating failure rate is about 10% of operating rate.**
- **Contamination in IC and other parts cause unwanted chemical reactions (mechanical parts fail because of fatigue, chemical reaction and flaws).**
- **Hydraulic parts fail because organic rubber seals outgas and cross link when exposed to heat & ultraviolet light.**

Protect Against Non-Operating Failures

- Solid rocket engines under go chemical degradation and can develop cracks.
- Other seals dry out and crack.
- Corrosion and rust affect components.
- Humidity and other environments cause damage.
- Components are damaged from vibration in transport.
- Loss and or deterioration of lubrication.
- Cycle of operation, power cycling, heat during operation evaporates moisture.
- Surface film resistance on contacts.
- Wide range of storage temperatures.
- Contaminants from the manufacturing process.

Why Standardize?

- Whether we are talking about standard car components or a standard spacecraft propulsion system or a standardized nuclear reactor with common componentry, we have to work toward standardization. It saves time, money and results in better products.
- With many common components we begin to accumulate enough reliability data to have real assurances that the product will satisfy our customers.
- We really begin to know design variables.
- We see what process variables contribute to higher quality and reliability.
- We see what failure modes actually occur.
- We can justify more testing with common components.

Mfg. Process Improvements

- Majority of defects are caused by out of control process (vs. design and use).
- Getting control of the process improves reliability and quality.
- Limit the number of suppliers.
- Work with the suppliers to improve their processes.
- Have qualified lines.
- Long term contracts encourage better tooling.

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Conclusion

- We need to do more than just measure reliability--rather we need to look for ways to improve it.
- Changes in the design, robust designs, built in test and fault diagnosis, fault tolerance are some of these methods.
- Manufacturing process improvement is a critical area where reliability can be improved. Process improvements, SPC, tighter tolerances, etc. all play a part in this.
- Standardization, reliability allocation and parts derating are other methods to improve reliability.

WRITING SPECIFICATIONS

SPECIFICATIONS

- **A detailed and exact statement of particulars, especially a statement prescribing materials, dimensions, and workmanship for something to be built, installed or manufactured.**

Why Important:

- Specifications if written correctly set out the exact details of what is to be done.
- They convey the requirements of what is to be done and in what manner it is to be done.
- This communication is the key to transferring knowledge and in educating the contractor.
- Specifications should spell out the process of manufacture and the management and corrective action system. If this is done, not only will design technology be transferred, but also management & process technology will be transferred as well. This will upgrade the contractors overall ability to produce a quality product and a reliable product.

OBJECTIVES:

- Be able to answer (or know):
- What should be the principles behind reliability specifications?
- What are the design requirements affecting reliability?
- What are the main reliability activities in a project?
- What questions should be asked during a design review regarding reliability?

OUTLINE:

- Writing Reliability Specifications.
- Design Requirements Affecting Reliability.
- Specifying Reliability Activities During each Program Phase.
- Design Reviews and Reliability.
- Contractual Provisions.

Writing Reliability Specifications:

- Reliability's main task is to identify reliability problems early in the program.
- The design reliability requirements should be accurately stated in terms of measurable results, not just high-sounding generalities.
- Maximum allowable failure rates for each given operating mode should be stated.
- Numbers should be based on intended & potential use.
- Prior product experience (failure rates and modes) should be considered.
- Resulting specifications should be attainable.

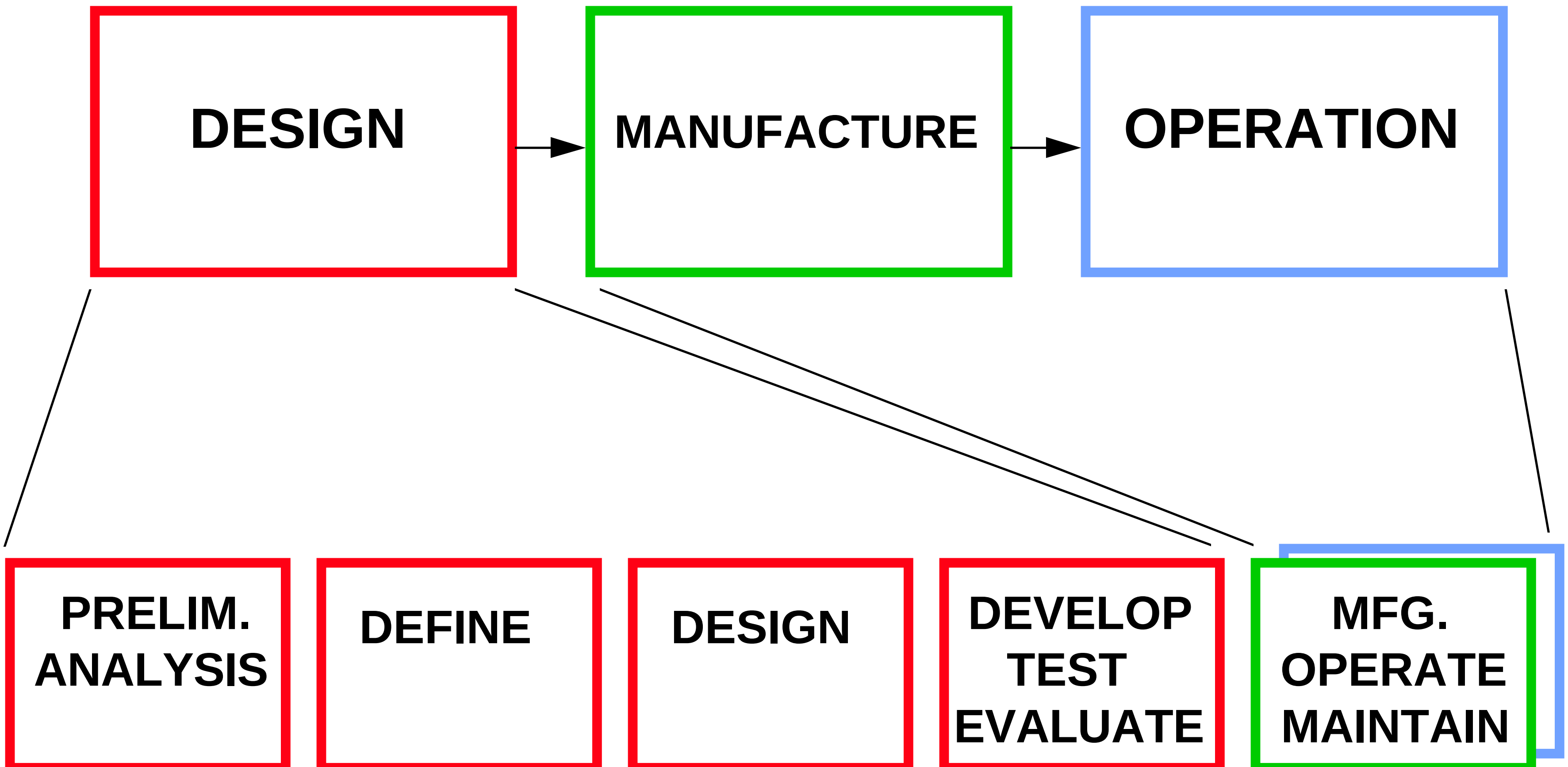
Design Requirements Affecting Reliability

- Installation and start-up requirements.
- Service and maintenance requirements.
- Environmental requirements.
- Packaging, storage and transportation.
- Use and future use.
- Reliability demonstration requirements.
- Software documentation, design and maintenance requirements.

Table-ES

Specifying Reliability Activities During each Program Phase:

EXPANSION of the Design Manufacturing and Operation Process



ASSURANCE: RELIABILITY ENGINEERING

PHASE A PRE. ANALY.	PHASE B DEFINE	PHASE C DESIGN	PHASE D DEVELOP/TEST	PHASE E -PROD, OPER., MAINT.

RELIABILITY MANAGEMENT

MONITOR/CONTROL SUBCONTRACTORS

PROGRAM REVIEWS

PROBLEM REPORT & COR.ACT;LL

FAILURE REVIEW BOARDS

RELIABILITY MODELING

RELIABILITY ALLOCATION

RELIABILITY PREDICTION

FAILURE MODE & EFFECTS ANALYSIS

CRITICAL ITEMS LIST

FAULT TREE ANALYSIS

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ASSURANCE: RELIABILITY ENGINEERING (con't)

PHASE A PRE. ANALY.	PHASE B DEFINE	PHASE C DESIGN	PHASE D DEVELOP/TEST	PHASE E -PROD, OPER., MAINT.

SNEAK CIRCUIT ANALYSIS

ELECTRONIC TOLERANCE

MECH.PARTS ANALYSIS

PARTS PROGRAM (Using Failure Rate Data)

EFFECTS TEST, STORAGE, HANDLING etc.

TESTING: ENVIRONMENTAL STRESS SCREEN

RELB. GROWTH TESTS

RELB./QUAL.TEST PROGRAM

RELIABILITY GROWTH TESTING

PRAT PROGRAM

SOFTWARE RELIABILITY & QUALITY ASSURANCE

Design Review Checklist for Reliability:

- **Could existing off-the-shelf components be used/modified?**
- **What are the potential failure modes?**
- **What is the failure history of similar hardware?**
- **What are the critical items?**
- **Have stress levels been determined & parts derated?**
- **Has a value analysis been performed on each part?**
- **Have human factors in assembly and operation been considered?**

Design Review Checklist
(continued):

- Are interface tolerances compatible?
- Are there any wear points for cabling, hoses or other "loose" items?
- Has design for manufacturability, disassembly been performed?
- Have the reliability activities for the program phase been performed?
- Have the structural and electrical analyses been performed and reported?
- Can the product be inspected?
- Are hazards identified and correlated with the Critical Items List?

Contractual Provisions:

- All of the above.
- Manufacturing review.
  - facility review and quality program review.
  - quality surveillance program.
  - supplier inspection data.
  - first article samples.
- Reliability specifications
- Software quality.
- Customer support.

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CONCLUSION-Specifications

- Specify reliability requirements early in the program.
- Consider all phases of the product life cycle.
- View reliability specifications as an opportunity to educate the customer and transfer technology.
- Set quantified and attainable reliability and maintainability goals.
- Encourage development of an organization to support the documents and requirements. Is it necessary to force compliance with the letter of the contract?

END